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N64-15536

CODE-1

CR-55664

Progress Report for October 1962
EVALUATION OF REGENERATIVE FUEL CELL

Prepared for

National Aeronautics and Space Administration
Western Operations Office
150 Pico Boulevard
Santa Monica, California

Contract NAS 7-181

EOS Report 3310-ML-3

7 November 1962

OTS PRICE

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1. INTRODUCTION

Considerable improvement in cell performance has been accomplished during October. This has been due, in part, to an improved catalyst for hydrogen electrodes but the improvement has also resulted from an understanding of other parameters affecting cell performance. Somewhat more work was done during the month on hydrogen-oxygen cells than on hydrogen-silver oxide cells, but studies concerning the hydrogen electrode are applicable to both.

An attempt to correlate performance characteristics of silver oxide electrodes with resistivity for several doped silver oxides is now under way. In two cases the doping process has significantly reduced the oxide resistivity, but initial results of the electrode testing have not definitely shown a correlation between resistivity and electrode performance. The silver oxide electrodes are much better than all previous ones both from the standpoint of polarization and charging capacity, but it now appears likely that the improvement is due to some other factor.

2. HYDROGEN ELECTRODES

Several factors influencing performance of hydrogen electrodes were studied during the month. Studies which were either completed or partially completed are outlined below.

2.1 Pressure Dependence

The range of pressures studied was from 50 to 95 psig. In this range the performance of the hydrogen electrode is independent of gas pressure.

2.2 Effect of Mixed Catalysts

It has been discovered that mixed platinum-palladium catalysts are superior to either catalyst alone. Polarization studies on the hydrogen electrode have shown that 50 percent (by weight) of platinum and 50 percent palladium is the optimum ratio. The plating is accomplished by the method described in the previous report, but the plating solution is a mixture of H_2PtCl_6 and PdCl_2 .

2.3 Effect of Excess Ba^{++}

In order to remove carbonate ion from the electrolyte, $\text{Ba}(\text{OH})_2$ is added, which precipitates carbonate as BaCO_3 . This is allowed to settle and the solution is used from the top. In order to ascertain the effect of an excess of Ba^{++} , experiments were designed in which various known concentrations of Ba^{++} were present in the electrolyte. These experiments have not been completed but it is apparent already that excess Ba^{++} , at least for the discharge process, does not affect the performance of the hydrogen electrode.

2.4 Effect of Excess $\text{CO}_3^{=}$

Similar experiments are in progress to test the effect of carbonate ion, which is present in the untreated electrolyte. It has been

found for the discharge process that $\text{CO}_3^{=}$ has a decided adverse effect on the hydrogen electrode polarization.

3. SILVER OXIDE ELECTRODES

Ten different doped silver oxides were prepared by the coprecipitation method as described in the preceding report. Doubly-charged positive ions of iron, cobalt, nickel, zinc, cadmium, mercury, manganese, copper, lead, and palladium replaced the singly-charged silver ion to the extent of 0.5 percent on an atomic basis. Resistivity measurements were made on each and compared to that of pure Ag_2O , prepared in a similar manner. In only two cases was a decided decrease in resistivity noted. The resistivity of the manganese doped oxide was lower by a factor of ten as compared to the pure silver oxide, and the cobalt doped material was lower by almost a factor of 100. However, it has not yet been established whether or not this lowered resistivity is contributing to better polarization characteristics or greater charging capacity. Much better results from both standpoints have been achieved recently, but there appears to be no difference between the doped and undoped electrodes. The improved performance of the silver electrodes made recently is due possibly to other factors. For example, the silver oxide paste was originally washed well with water and partially dried on a Buchner funnel. Recently this procedure has been followed with a wash with the KOH electrolyte in order to prevent pH gradients from being set up within the electrode.

Some work has also been done concerning the pressure dependence of the hydrogen-silver oxide cells. It has been found that about 50 percent more electrolyte must be used in one of these cells than in a corresponding hydrogen-oxygen cell. If the same amount of electrolyte is used for the hydrogen-silver oxide cell as has been found to be optimum for a hydrogen-oxygen cell, then the hydrogen electrode polarization is very pressure dependent and becomes progressively worse as the pressure

becomes higher. It seems probable that the electrolyte is being forced into openings in and around the silver oxide electrode, the more so the higher the pressure. If 50 percent more electrolyte is used, then hydrogen electrode performance is as good as in the hydrogen-oxygen cell and in the range of 50 to 95 psig there is no longer a pressure dependence. More electrolyte than this, however, floods the hydrogen electrode at all pressures, no matter how high.

4. OXYGEN ELECTRODES

Very little work has been done on oxygen electrodes per se. However, several factors affecting oxygen electrode performance have been studied. The results are described below.

4.1 Pressure Dependence

In contrast to hydrogen electrodes, oxygen electrodes at room temperature are quite sensitive to pressure in the pressure range studied. The electrodes perform better with increasing pressure. In addition to the effect of total pressure, it has also been found that oxygen electrodes are more sensitive to flooding than are hydrogen electrodes. If the gas pressure at either side is increased over that at the other, then the electrode at the low pressure side begins to show severe concentration polarization. The hydrogen electrode can tolerate a differential of 1 to 2 psi while the oxygen electrode cannot. In fact, the oxygen electrode often works best if the oxygen pressure is about 1 psi higher than the hydrogen pressure. These results are presumably due to flooding and the difference in behavior of the two electrodes likely reflects the lower diffusion rate through the electrolyte film for oxygen.

4.2 Effect of Excess Ba^{++}

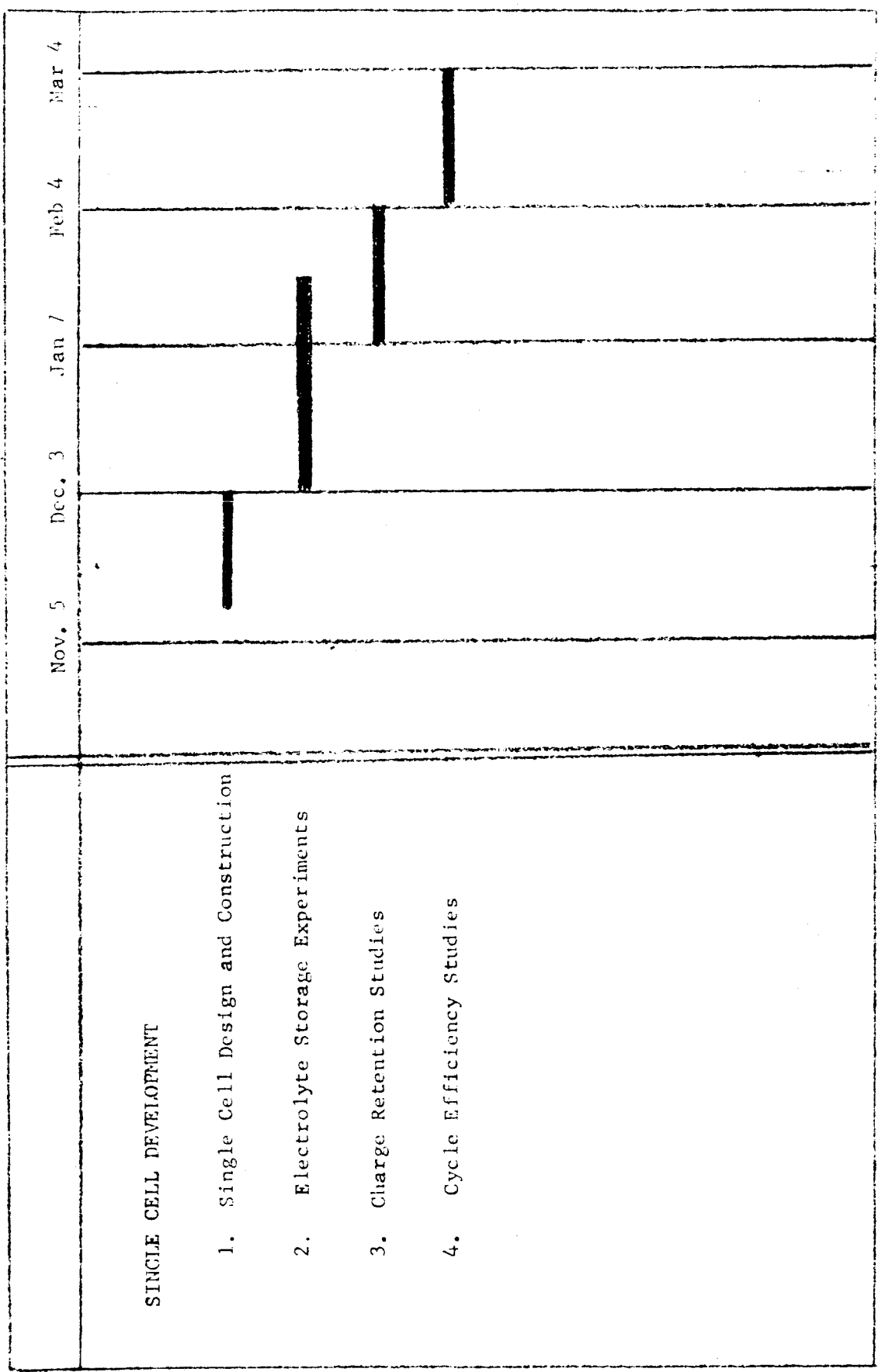
On discharge, the presence of excess Ba^{++} has a pronounced, adverse effect on the performance of the oxygen electrode. This is in sharp contrast to the effect on the hydrogen electrode.

4.3 Effect of Excess $CO_3^{=}$

Again on discharge the effect of excess $CO_3^{=}$ is not the same for the oxygen electrode as for the hydrogen electrode. The presence of carbonate has thus far been shown to have no effect on oxygen electrode polarization. The effects described in Sections 2.3, 2.4, 4.2, and this section can be understood in terms of the presence of a foreign cation

or a foreign anion. At least for the discharge process, the presence of the foreign cation (Ba^{++}) adversely affects the cathode only, while the presence of a foreign anion (CO_3^{--}) adversely affects only the anode. The importance of a very pure KOH electrolyte is apparent.

PHASE II - SINGLE CELL DEVELOPMENT



5. FUTURE PLANS

During November, the electrode studies will be completed. For the hydrogen electrode the following parameters will be studied:

Temperature dependence

KOH concentration dependence

Hydrogen storage in palladium

The following studies will be made for the silver oxide electrode:

Temperature dependence

KOH concentration dependence

Radioactive electrodes

The following studies will be made for the oxygen electrode:

Temperature dependence

KOH concentration dependence

Radioactive electrodes

Phase II of the present contract, "Single Cell Development", will begin during November. It is anticipated that this phase will be carried out approximately as indicated in Fig. 1.